

Influence of body weight, age, and weight gain on fertility and prolificacy in four breeds of ewe lambs¹

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ABSTRACT: Breeding ewes to lamb at 1 yr of age can improve profitability for some production systems. The first objective of this study was to evaluate the effect of age and weight at breeding and total postweaning weight gain on reproductive performance of ewe lambs. The second objective was to compare the effects of weight and age variables in four major sheep breeds (Columbia, Polypay, Rambouillet, and Targhee). Weights, ages, and the binary traits of fertility (pregnant or nonpregnant) and prolificacy (one lamb born vs. two or more) were collected on 2,055 ewe lambs at the U.S. Sheep Experiment Station, Dubois, ID, from 1984 through 1988. The effects of age and weight at breeding and total weight gain from weaning to breeding on fertility and prolificacy were analyzed with a logit model in a maximum likelihood analyses. Differences ($P < 0.001$) among breeds for fertility were identified, with a 93% fertility rate for Polypay ewe lambs compared with lower fertility rates in Columbia, Targhee, and Rambouillet ewe lambs (50, 60, and 75%, respectively). The percentage of multiple births (prolificacy rate) also was higher ($P < 0.001$) in the Polypay (47%) than in

Columbia, Targhee, and Rambouillet breeds (1, 13, and 14%, respectively). Averaged across breeds, weight at breeding had a positive effect on fertility and prolificacy ($P < 0.001$), whereas total weight gain from weaning to breeding had a positive effect only on fertility ($P < 0.027$). In separate analyses for each breed, increasing age ($P < 0.001$) and weight at breeding ($P < 0.001$) increased the probability of pregnancy in Rambouillet ewe lambs. The probability of pregnancy for Targhee ewe lambs increased ($P < 0.005$) with weight at breeding. Increasing weight at breeding increased ($P < 0.004$) the probability of multiple births in all breeds. Increasing total postweaning weight gain increased ($P < 0.007$) the probabilities of multiple births in Rambouillet and Targhee ewe lambs. In conclusion, Polypay ewe lambs were superior in fertility and prolificacy to Columbia, Rambouillet, and Targhee under Western range conditions. Improved reproductive performance of Columbia, Rambouillet, and Targhee ewe lambs may be achieved by increasing age and weight at breeding and postweaning gain.

Key Words: Efficiency, Litter Size, Reproduction, Sheep

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J. Anim. Sci. 2005. 83:1680–1689

Introduction

Increasing the level and efficiency of lamb production is of interest to commercial sheep producers because the percentage of gross receipts from lamb sales has increased relative to wool production in recent years (Snowden, 2002). Breeding ewe lambs is one approach to increase lamb production. Ewes bred as lambs have a higher lifetime production rate compared

with those bred as yearlings (Hulet et al., 1969; Baker et al., 1978); however, the fertility and prolificacy rates of ewe lambs are lower than those of adult ewes (Turner et al., 1968). Knowledge of genetic and environmental factors influencing ewe lamb reproduction will aid in improving reproductive rates of ewe lambs.

We hypothesized that fertility (lambled vs. did not lamb) and prolificacy (one lamb vs. two or more) will increase with greater weight or older ages at breeding, and that breeds will differ in response to these traits. Fertility and prolificacy of ewe lambs need to be characterized for weight and age at breeding, as well as other factors. Specific objectives included the following: 1) determining whether changes in age and weight at breeding and postweaning weight gain affect fertility and prolificacy in ewe lambs bred at 8 mo of age, and 2) comparing the relative differences of fertility

¹Appreciation is expressed to the USDA, ARS, U.S. Sheep Exp. Stn., Dubois, ID, for contributing the data and graduate student financial support for this study.

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Received October 22, 2004.

Accepted March 30, 2005.

and prolificacy in ewe lambs among Rambouillet, Columbia, Targhee, and Polypay breeds.

Materials and Methods

Records from ewe lambs of four sheep breeds (Columbia, Polypay, Rambouillet, and Targhee) at the ARS, USDA U.S. Sheep Experimental Station in Dubois, ID, from 1984 through 1988 were evaluated. Ewe lambs were born in April and reared with their dams on spring (sagebrush and bunchgrass, April to May) and summer (high mountain meadow, June to early September) ranges. Weaning occurred the first week of September. Selection of replacement ewe lambs was based on 120-d weaning weights adjusted for management flock, age of dam, and type of birth and rearing using a least squares analysis of the data each year. Independent culling criteria removed ewe lambs weighing less than 27 kg, those with high face cover scores for wool blindness, dark-colored fleece spots, malformed jaws, or other health problems. Remaining ewe lambs (approximately 60% of those weaned) grazed fall pastures (sagebrush and bunchgrass) from weaning until entering drylot in October. In the drylot, ewe lambs had ad libitum access to a mixed diet of 40% whole barley and 60% alfalfa pellets on an as-fed basis. From approximately November 5 until December 28, ewe lambs were pen-bred to multiple sires within their own breed. Age (lambs, yearlings, and mature) and mating experience (naïve to 2 yr of previous breeding exposure) of rams varied across years. The approximate breeding ratio was one ram per 32 ewe lambs. Only rams with acceptable semen tests were used (Perkins et al., 1992).

Sixty days after ram removal, all ewes were tested for pregnancy by real-time ultrasound (Vetscan 2 with a 3.5-MHz, 170° sector scan probe from BFC Technology, Ltd., Livingston, U.K.). After pregnancy diagnosis, ewe lambs were returned to drylot and received a diet of approximately 86% long-stemmed alfalfa hay and 14% whole barley grain on an as-fed basis until lambing in April. Feeding and management practices were consistent across all years.

Growth and reproductive performance of ewe lambs were measured on 2,055 lambs born in 4 yr. Type of birth and rearing of ewe lambs included three categories: born and raised as a single, born and raised as a twin, and born as a twin and raised as a single.

Dichotomous traits designated as "fertility" and "prolificacy" were analyzed. The designation of fertility was 0 if no lambs were born, and 1 if lambs were born, and the designation of prolificacy was 0 if one lamb was born and 1 if two or more lambs were born. This method of coding resulted in means for the fertility trait expressed as a percentage of ewe lambs with one or more lambs.

The data were analyzed by maximum likelihood procedures for a logit model using PROC CATMOD in SAS (SAS Inst., Inc., Cary, NC). This is a statistical

methodology that uses a linear model approach for the analysis of a binary dependent variable that is not normally distributed. Logits are defined as $\ln(p_i)/[1 - \ln(p_i)]$, where $\ln(\cdot)$ represents the natural log and p_i represents the probability of a success for the i th observation. Logits are assumed to be linear functions of the model parameters. Here, the function $p_i/(1 - p_i)$ represents the odds of a success for the response at the i th observation relative to a failure. Estimates of parameters are computed for each level of each main effect and interaction specified in the linear model.

Estimates of class and subclass means were obtained from linear functions of the elements in the vector of parameter estimates (\hat{B}). The linear functions are defined in the rows of a matrix L and the means are equal to $L'\hat{B}$. The antilogit of the linear function, $e^{L'\hat{B}}/(1+e^{L'\hat{B}})$ results in the estimated probability values. Standard errors of the linear contrasts were computed as $L'\hat{B}*(I - L'\hat{B})/\sqrt{\text{diagonalvector}(L'\hat{B}*V*\hat{B}'L)}$,

where $\text{diagonalvector}(L'\hat{B}*V*\hat{B}'L)$ represents the diagonal elements of the matrix and V is the variance-covariance matrix of \hat{B} .

Partial regression coefficients were computed for the continuous independent variables, but interpretation of these coefficients differs from traditional regression coefficients. The computed coefficients are the change in the natural log of the ratio (of the odds) of the probability of a ewe lamb being pregnant to the odds of the probability of a ewe lamb not being pregnant per one unit change in the covariate.

The log odds ratios were transformed into probability values that have a more common interpretation. The ratios were transformed by reversing the sign, which inverts the ratio, and then taking the antilog. This operation is e^{-b_i} , where b_i is an element of \hat{B} corresponding to the covariate. For fertility, the resulting values (odds ratios) were then interpreted as the change in the odds of a ewe lamb being pregnant relative to the odds of a ewe lamb being nonpregnant per unit change in the covariate. For example, a transformed coefficient of 1.10 for fertility would indicate an expected 10% increase in the ratio of the odds of a ewe lamb being pregnant relative to the odds of being nonpregnant per one unit change in the covariate. A coefficient of 1.0 would indicate no change in the odds ratio, and a coefficient of 0.90 would indicate a decrease of 10% in the odds ratio. For prolificacy, the values were interpreted as the change in the odds of a ewe lamb having two or more lambs relative to the odds of a ewe lamb having only a single lamb per unit of change in the covariate.

For both fertility and prolificacy, the initial statistical model included fixed effects for breed, year of birth, breed \times year interaction, type of birth and rearing, year \times type of birth and rearing interaction, and covariates of age and weight at breeding, and total weight gain from weaning to breeding, and interactions of covariates \times breed. Class and subclass means (proba-

Table 1. Numbers of ewe lambs exposed at breeding by breed and year

Breed	Year				Total
	1984	1985	1986	1987	
Targhee	97	102	74	106	379
Columbia	153	147	147	188	635
Rambouillet	151	153	152	170	626
Polypay	102	104	103	106	415
Total	503	506	476	570	2,055

bilities) for main effects and interactions were computed from parameter estimates as described above. Differences among main effect breed means were tested using a protected *t*-test of four nonorthogonal contrasts. The contrasts were Polypay vs. all others and three pairwise tests among Targhee, Columbia, and Rambouillet.

The effects of some covariates were not the same for all breeds. Therefore, subsequent statistical models analyzed each covariate separately for each breed to determine the effect of the covariate on fertility and prolificacy. Models for these analyses included year, type of birth and rearing, year \times type of birth and rearing interaction, and one of the three covariates. Linear trend lines for the estimated probability values in fertility and prolificacy were computed over the actual range of values for the covariate by using the estimated intercept and the regression coefficient from the logit model. These values were then transformed from the logit to the fertility or prolificacy scale, and therefore the transformed values were not necessarily linear with the covariate. Estimates of the standard errors of the predicted value at the mean of the covariate are the same as the standard error of the mean at the mean of the covariate. These overall breed means and standard errors are shown in Tables 3 and 4; estimates of standard errors of the predicted lines increase the more the value of the covariate differs from its mean.

Results and Discussion

The number of ewe lambs exposed to rams is summarized by breed and year in Table 1, and Table 2 shows

Table 2. Means and standard deviations of age and body weight at breeding and total postweaning weight gain for ewe lambs exposed at breeding

Breed	Age, d		Weight, kg		Weight gain, kg	
	Mean	SD	Mean	SD	Mean	SD
Targhee	195	6.7	49.3	5.7	15.1	3.5
Columbia	210	6.0	53.4	5.7	14.6	3.4
Rambouillet	209	6.0	47.3	5.6	12.9	3.0
Polypay	214	5.1	50.4	5.0	13.8	3.2
Overall	208	8.6	50.2	6.0	14.0	3.4

the means and standard deviations for each of the three covariates for each breed. Columbia, Rambouillet, and Polypay ewe lambs were similar in age and approximately 16 d older than Targhee ewes. Weights at breeding were similar for all breeds, but total weight gains from weaning to breeding were greater for Targhee and Columbia than for Polypay, with Rambouillet gaining the least. Standard deviations were similar across breeds for each of the three covariates.

The range in values of the covariates varied according to breed, especially for age at breeding. The range in the age at breeding for the Polypay was shorter (199 to 224 d of age) than that of the Columbia (175 to 222 d of age), Targhee (167 to 218 d of age), and Rambouillet (168 to 223 d of age), which were similar to each other. The smaller range in the age at breeding in the Polypay was attributed to the higher fertility of this breed during early exposure to rams. The range of the covariates may be similar to those of Western range commercial flocks. Because the range of each covariate for each breed in this study limits the interpretation of the results to similar populations, future studies may be required to examine the effects of different ranges in the covariates on fertility and prolificacy. Correlations among the covariates were fairly consistent across breeds. Phenotypic correlations between age and weight at breeding ranged from 0.10 to 0.21, and for age at breeding and gain from -0.05 to 0.09, whereas the correlations between breeding weight and gain were higher (0.53 to 0.73).

Fertility

Chi-square tests indicated that breed, year, and breed \times year interaction were important effects ($P < 0.005$). The effect of type of birth and rearing also affected fertility ($P < 0.007$), but not the interaction of year with type of birth and rearing ($P = 0.096$).

Table 3 shows the estimated probabilities and standard errors (computed from the logit analysis and converted back to the probability scale) for the breeds, years, and breed \times year subclasses. Polypay ewe lambs had higher ($P < 0.001$) and less variable fertility rates over the 4 yr than did Targhee, Columbia, and Rambouillet ewe lambs. Fertility rates did not differ ($P > 0.110$) among Targhee and Columbia ewe lambs, which were lower ($P < 0.021$) than the fertility rates in Rambouillet. The average estimated probabilities for pregnancy for Rambouillet and Targhee ewe lambs were higher than the actual percentage of ewes lambing, as previously reported by Southam et al. (1971; 52 and 64%), but the average estimated probability for Columbia ewe lambs was approximately 50%, which was less than the value of 72% observed by Southam et al. (1971).

Years exhibited variability in ewe fertility rates ($P < 0.001$), with 1984 being the lowest, followed by 1987, with 1985 and 1986 being similar and having the highest fertility rates. There also was considerable varia-

Table 3. Estimated probabilities (\pm SE) of ewe lambs becoming pregnant (fertility) by year and breed

Breed	Year				Breed ^a
	1984	1985	1986	1987	
Targhee	0.33 \pm 0.071	0.77 \pm 0.062	0.62 \pm 0.075	0.68 \pm 0.068	0.61 \pm 0.060
Columbia	0.39 \pm 0.045	0.60 \pm 0.047	0.51 \pm 0.055	0.49 \pm 0.043	0.50 \pm 0.027
Rambouillet	0.70 \pm 0.042	0.70 \pm 0.042	0.85 \pm 0.035	0.71 \pm 0.039	0.75 \pm 0.024
Polypay	0.87 \pm 0.044	0.93 \pm 0.029	0.97 \pm 0.023	0.91 \pm 0.037	0.93 \pm 0.023
Year	0.60 \pm 0.038	0.78 \pm 0.029	0.81 \pm 0.035	0.73 \pm 0.031	

^aBreed differences tested with nonorthogonal contrasts. Polypay differs from all others, $P < 0.001$; Rambouillet differs from Columbia, $P < 0.001$; Rambouillet differs from Targhee, $P < 0.021$.

tion among years within the breeds. In 1986, the fertility rate for Rambouillet ewe lambs was higher than in other years. In 1984, fertility rates of Targhee and Columbia ewe lambs were noticeably lower than subsequent years. The breed \times year interaction ($P < 0.005$) was attributed to fluctuations in fertility rates of Targhee and Columbia ewe lambs across years. Yearly variation within a breed may be partially explained by the ram effect because different rams were used each year. Some of the variability in fertility among breeds may be attributed to the inherent differences for pubertal age. Large variations among yearly values for reproductive performance of ewe lambs are not uncommon and have been reported previously (Burfening et al., 1971).

Fertility rates were influenced by weight at breeding ($P < 0.001$) and total weight gain from weaning to breeding ($P < 0.027$). Higher fertility rates of ewe lambs are generally associated with heavier BW and faster growth (Bowman, 1966; Dickerson and Laster, 1975; Dýrmundsson, 1981); however, Laster et al. (1972) reported that BW at breeding did not influence fertility of ewe lambs bred at an average age of 217 d.

Age of ewe lamb at breeding did not affect fertility rate when averaged over breeds ($P = 0.736$). Generally, older ages at breeding are associated with higher reproductive performance in ewe lambs (Laster et al., 1972; Dýrmundsson, 1973). Most of the mean values for age at first estrus cited in the literature are within a range of 6 to 18 mo, dependent of season of birth, breeding season, geographic locality, nutrition, and other genetic and environmental factors (Dýrmundsson, 1973). Age at first behavioral estrus commonly differs among breeds, but differences in age at first ovulation (silent estrus) can be small (Quirke et al., 1985). The ewe lambs in this study were exposed at an average age of 208 d; therefore, the age effect on fertility rate across these breeds may not have been significant because of their older initial age at breeding.

There were interactions of weight at breeding ($P = 0.002$) and gain from weaning to breeding ($P < 0.051$). For that reason, separate analyses were conducted to determine the affects of each covariate with each breed. Breed-specific analyses indicated breed differ-

ences in response to the covariates for fertility rates of ewe lambs. The relationships of age at breeding and the estimated probabilities of a ewe lamb becoming pregnant by breed are shown in Figure 1. All predicted regression lines were linear on the logit scale; however, when converted back to the probability scale, the slope of the line for the Rambouillet was not linear. Only the slope for Rambouillet differed from zero ($P < 0.001$). Fertility rates of Polypay ewe lambs remained consistently high over a very narrow range of ages at breeding. Probability of pregnancy increased slightly with age at breeding in Targhee and Columbia ewe lambs. Estimates of probability of pregnancy (fertility) of Rambouillet ewe lambs at younger ages were low and unacceptable, but probability estimates increased rapidly between 185 and 220 d of age. Probability of pregnancy of Rambouillet ewe lambs surpassed that of Columbia and Targhee at approximately 188 and 197 d of age, respectively. These data suggest that Rambouillet ewe lambs have a delayed onset of puberty but a higher probability of pregnancy as they advance in age. It was previously reported that the average age for puberty in Rambouillet ewe lambs is approximately 6 d earlier than for Targhee and Columbia ewe lambs (Southam et al., 1971), but 19 d older than Finn crossbreds (Quirke et al., 1985).

In the present study, age at breeding or birth date was confounded with seasonal estrus. Therefore, the increased estimated probabilities of becoming pregnant at older ages in the Rambouillet also may be related to delayed onset of seasonal estrus in the Rambouillet compared with the other breeds.

Breed differences for the estimated probability of pregnancy in response to weight at breeding were detected (Figure 2). The range in weight at breeding was more uniform across breeds than the range in ages at breeding. Weight at breeding did not influence the probability of pregnancy in Polypay ewe lambs, and although the slope was slightly negative, it did not differ from zero ($P < 0.358$). The relationship of weight at breeding with the estimated probability of pregnancy was positive in Rambouillet, Targhee, and Columbia ewe lambs, indicating greater fertility as ewe lambs gained weight. The slope of the line for Columbia ewe lambs did not differ from zero ($P < 0.081$),

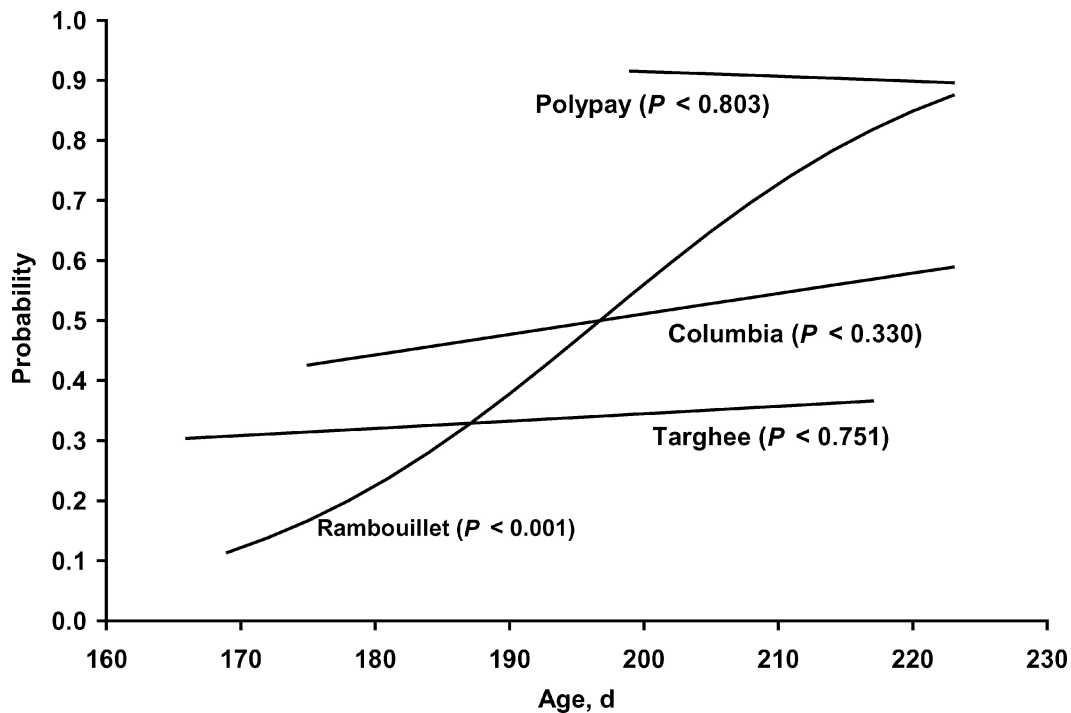


Figure 1. Estimated probabilities of pregnancy for four breeds of ewe lambs for different breeding ages. Estimated probabilities of difference of regression coefficients from zero are in parentheses.

whereas the slopes of the lines for Rambouillet ($P < 0.001$) and Targhee ($P < 0.005$) did. With the exception of the Polypay, the positive relationship between weight at breeding and fertility agrees with the major-

ity of previous studies (Laster et al., 1972; Dýrmundsson, 1973).

The interrelationship of age and weight at breeding on the probability of Rambouillet ewe lambs becoming

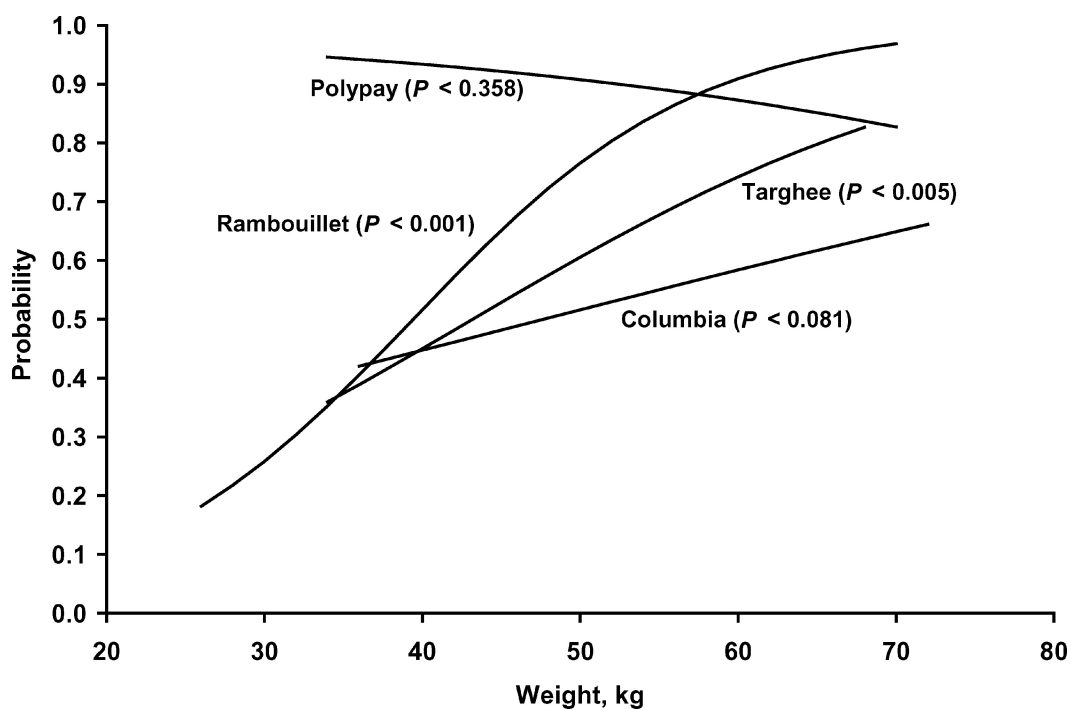


Figure 2. Estimated probabilities of pregnancy for four breeds of ewe lambs for different breeding weights. Estimated probabilities of difference of regression coefficients from zero are in parentheses.

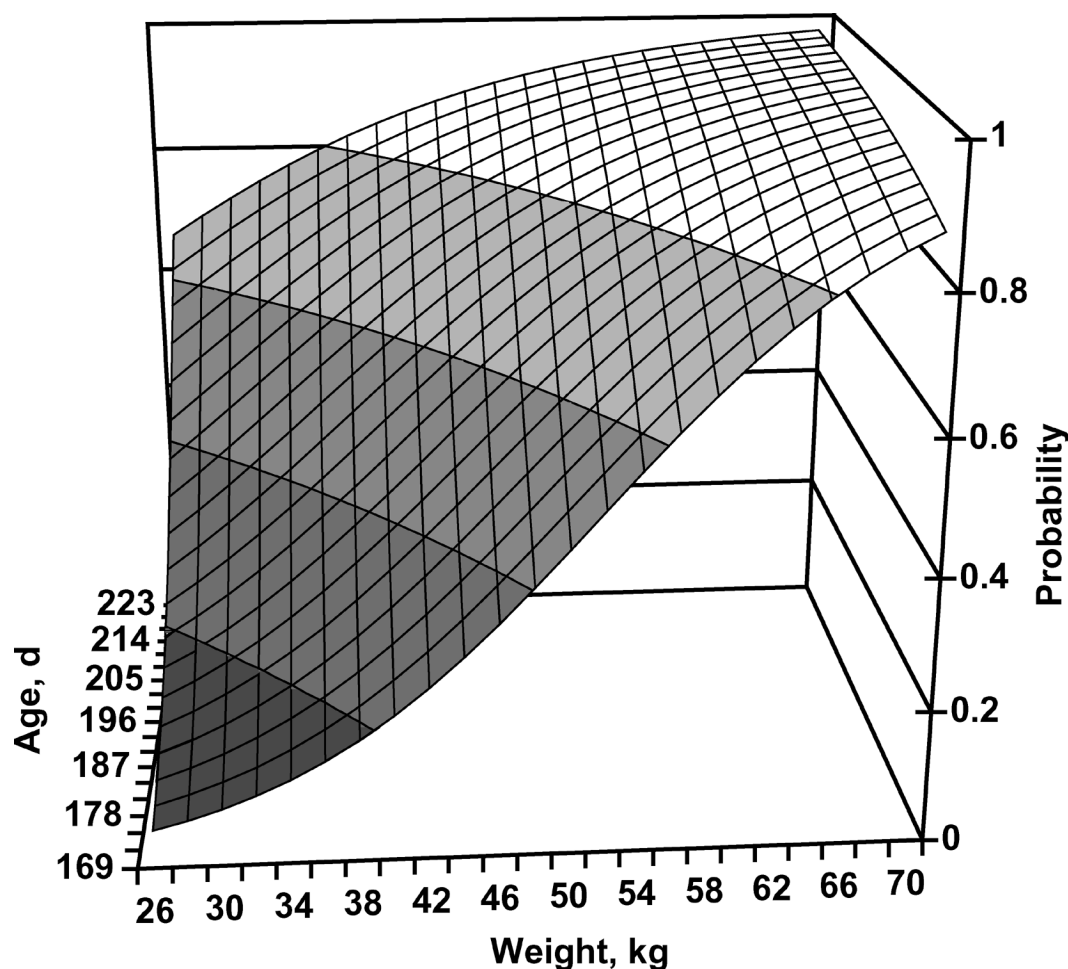


Figure 3. Interrelationships of different ages and weights at breeding on estimated probabilities of pregnancy for Rambouillet ewe lambs.

pregnant was depicted in Figure 3. The probability of pregnancy can be increased by breeding older and/or heavier ewe lambs. This information can assist sheep producers in making management decisions related to time of breeding and the economic return of feeding ewe lambs before weaning.

The effect of total weight gain from weaning to breeding on the estimated probability of being pregnant (fertility) was not large, except for Columbia ($P < 0.018$; Figure 4). Trends in the relationship of weight gain to estimated probability of pregnancy for Rambouillet, Polypay, and Targhee were positive. The results for the Columbia ewe lambs may indicate that growth before weaning is critical for Columbia lambs to achieve acceptable fertility. The negative trend in the Columbia is counterintuitive. Investigation by categorizing gain in 2-kg increments and simply computing percentages of ewe lambs that are pregnant showed a similar negative trend overall, but it also showed variation with both positive and negative trends in subsets of these categories. Improved nutrition and faster growth rates of ewe lambs have been reported to increase the fertility of ewe lambs (Allen

and Lamming, 1961; Burfening et al., 1971; Southam et al., 1971).

Prolificacy

Table 4 shows the estimated means (probabilities) and standard errors for breed, year, and breed \times year subclasses for prolificacy of ewe lambs. Targhee ewe lambs consistently had the lowest probability for multiple births, whereas Columbia and Rambouillet ewe lambs were similar and had a slightly higher probability of multiple births than Targhee. Polypay ewe lambs were clearly superior for producing multiple births. The higher reproductive efficiencies of the Polypay breed compared with other breeds have been previously reported (Nawaz et al., 1992; Knight and Snowden, 1995). The Polypay is a four-breed composite of Targhee, Rambouillet, Dorset, and Finnish Landrace breeds, and the higher prolificacy of the Polypay is associated with its Finnish Landrace ancestry (Cedillo et al., 1977; Ercanbrack and Knight, 1985; Lewis and Burfening, 1988).

The lowest frequency of multiple births across all breeds occurred in 1984. Because no multiple births

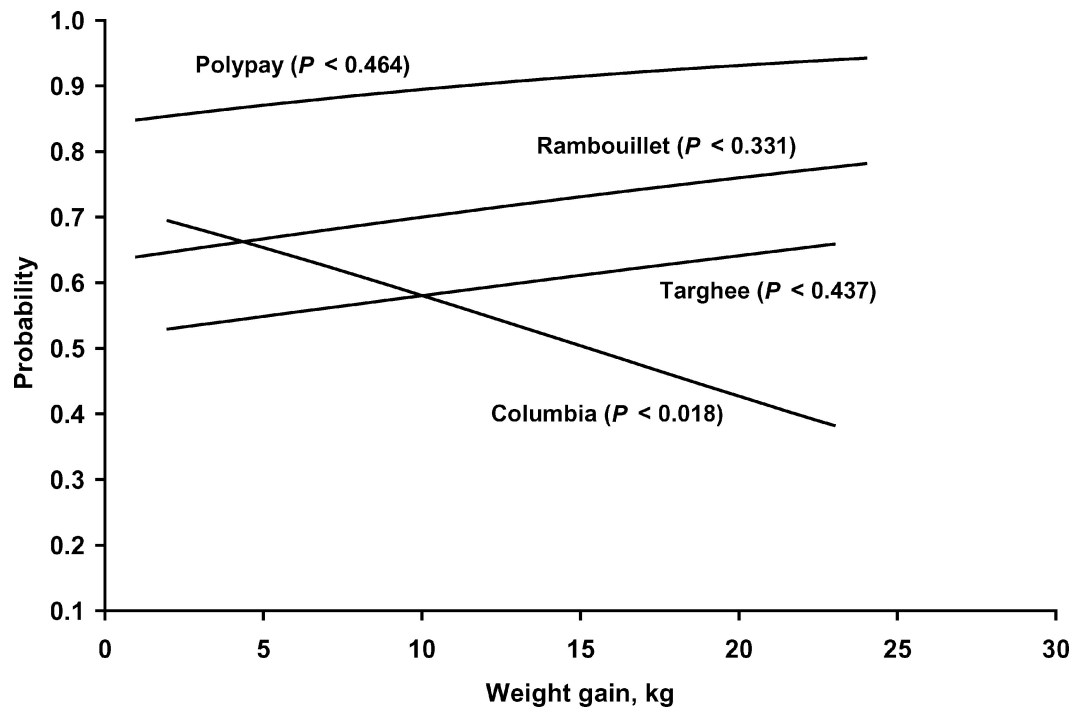


Figure 4. Estimated probabilities of pregnancy for four breeds of ewe lambs for different weight gains from weaning to breeding. Estimated probabilities of difference of regression coefficients from zero are in parentheses.

were observed in the Targhee ewe lambs in 1984, both the estimated mean (probability) and standard error of that cell were zero. Therefore, the main effect means and standard errors for the Targhee and for 1984 were lower than expected; this is a function of the logit model, which forces estimated probabilities to be between 0 and 1.

Age at breeding did not have an important effect on the estimated probability of multiple births (Figure 5) because none of the breed regression coefficients differed from zero ($P < 0.476$). Probabilities of multiple births remained fairly constant across ages within a breed. The Polypay breed maintained a higher probability for multiple births, approximately 50%, across the age range compared with the other breeds. Only one previous study evaluating the relationship of age and weight at breeding on ewe lamb prolificacy could be found. In that study, the average effect of age at

breeding across 19 breed groups had a positive influence on prolificacy (Laster et al., 1972).

Body weight at breeding had a positive influence on the probability of multiple births in all breeds (Figure 6). Even the Polypay breed, which was not affected by other covariates for either fertility or prolificacy, had a positive linear relationship ($P = 0.089$) between breeding weight and probability of multiple births. The Targhee breed had the greatest response ($P < 0.005$) to increased weight at breeding. Probabilities of multiple births at lighter weights were least in Targhee, but probabilities within this breed exceeded those of Rambouillet and Columbia at a breeding weight of approximately 60 kg. The relationships of breed weight and probability of multiple births were similar for Rambouillet and Columbia, with the probability of multiple births increasing with breeding weight; however, Laster et al. (1972) reported that

Table 4. Estimated probability (\pm SE) of pregnant ewe lambs giving birth to a multiple litter (prolificacy) by year and breed

Breed	Year				Breed ^a
	1984	1985	1986	1987	
Targhee	0.00 \pm 0.000	0.07 \pm 0.048	0.09 \pm 0.052	0.07 \pm 0.051	0.01 \pm 0.004
Columbia	0.04 \pm 0.022	0.20 \pm 0.046	0.12 \pm 0.039	0.24 \pm 0.049	0.13 \pm 0.024
Rambouillet	0.04 \pm 0.023	0.21 \pm 0.047	0.15 \pm 0.041	0.21 \pm 0.042	0.14 \pm 0.021
Polypay	0.27 \pm 0.070	0.56 \pm 0.069	0.47 \pm 0.094	0.61 \pm 0.064	0.47 \pm 0.047
Year	0.01 \pm 0.003	0.22 \pm 0.040	0.18 \pm 0.035	0.24 \pm 0.042	

^aBreed differences tested with nonorthogonal contrasts. Polypay differs from all others, $P < 0.001$; Targhee differs from Columbia, $P < 0.001$; Targhee differs from Rambouillet, $P < 0.001$.

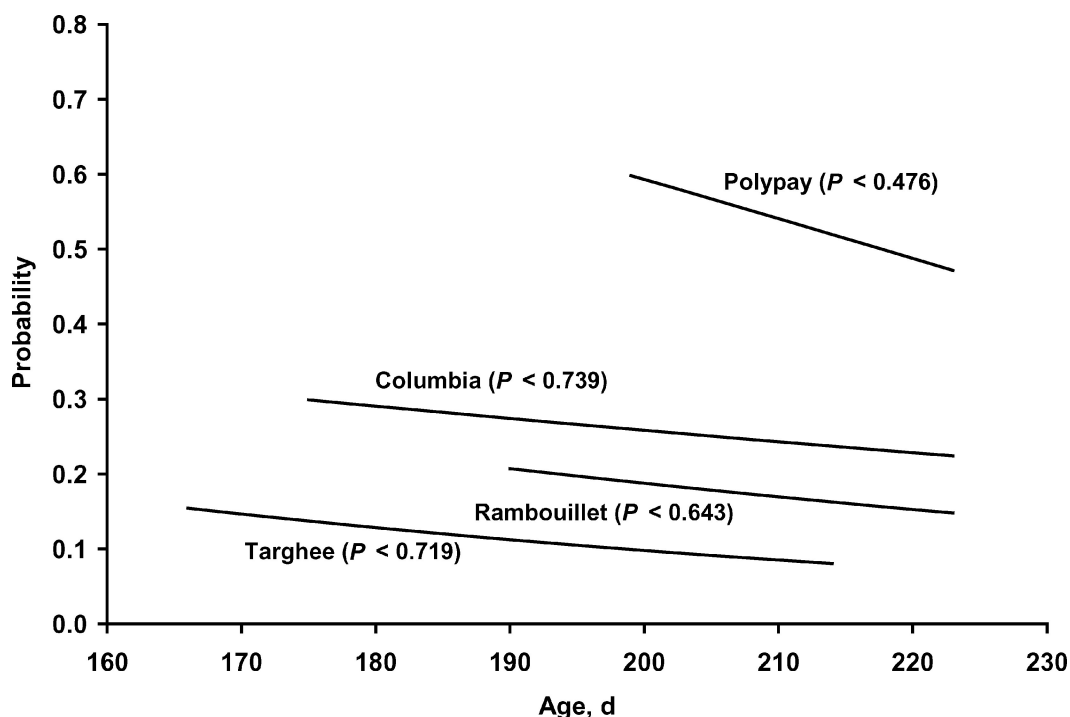


Figure 5. Estimated probabilities of two or more lambs for four breeds of ewe lambs for different breeding ages. Estimated probabilities of difference of regression coefficients from zero are in parentheses.

weight at breeding did not affect prolificacy of ewe lambs in 19 breed groups. In mature ewes, the positive relationship between weight at breeding and litter size or ovulation rate is well established (Smith, 1985).

The probability of multiple births of all breeds increased as lambs gained more weight from weaning to breeding (Figure 7), but only the slope of the lines for Targhee ($P < 0.001$) and Rambouillet ($P < 0.007$)

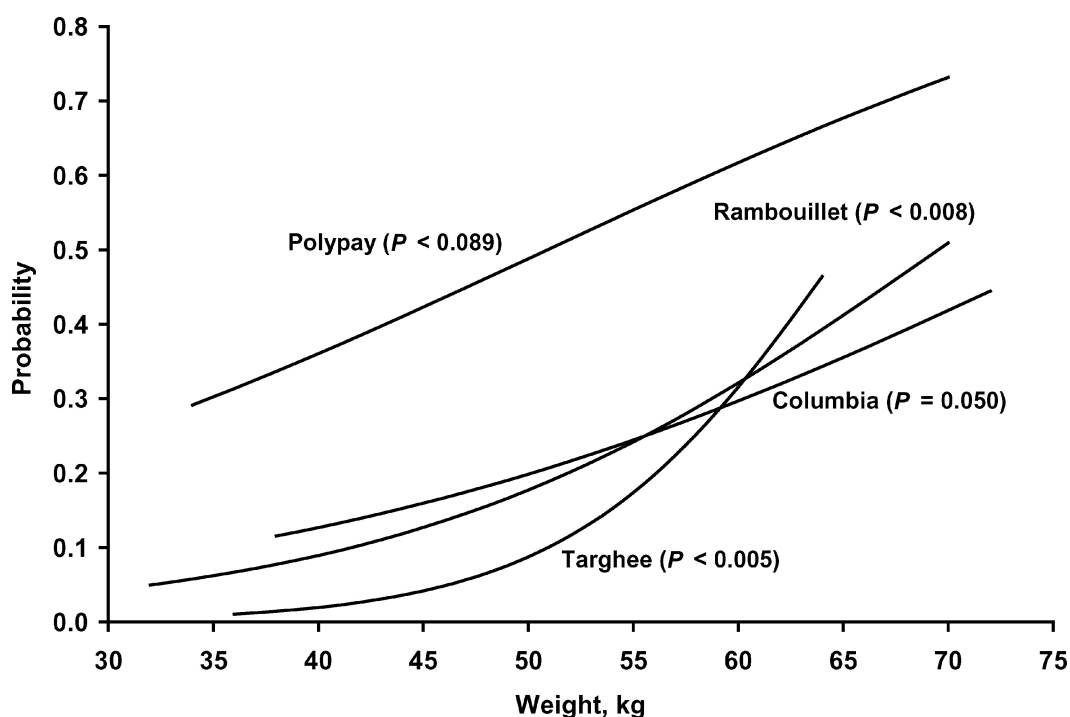


Figure 6. Estimated probabilities of two or more lambs for four breeds of ewe lambs for different breeding weights. Estimated probabilities of difference of regression coefficients from zero are in parentheses.

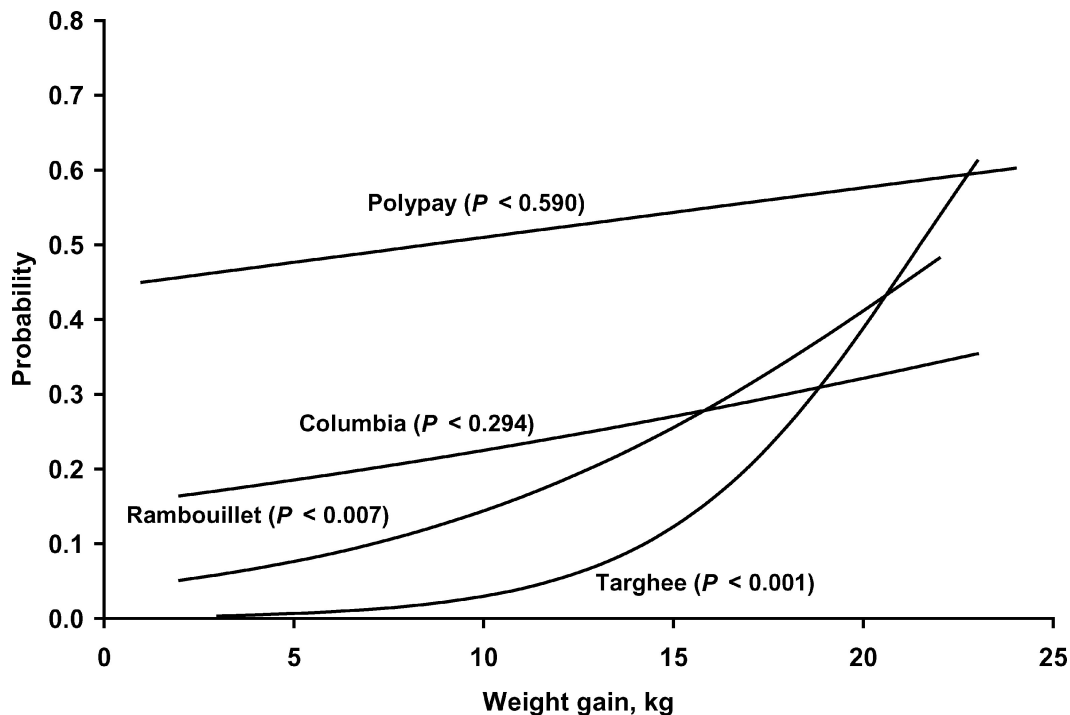


Figure 7. Estimated probabilities of two or more lambs for four breeds of ewe lambs for different weight gains from weaning to breeding. Estimated probabilities of difference of regression coefficients from zero are in parentheses.

differed from zero. In the Targhee, the shape of the probability curve for response to total weight gain resembled the response curve for weight at breeding. The strongly curvilinear response of the Targhee was near zero at lower gains, but it increased rapidly at higher gains, suggesting that a threshold for response occurred around 15 kg. The probability response for the Rambouillet also had a curvilinear shape but was lower compared with the Targhee. These findings are in general agreement with those of Smith (1985).

The decision of breeding ewe lambs also should consider potentially negative associated effects. Higher neonatal mortality of lambs born to ewes lambing at 1 yr of age has been reported (Dýrmundsson, 1973; Richard et al., 1974). Dystocia due to the birth of large single lambs in ewes lambing at 1 yr of age has been a concern (Laster et al., 1972). Mothering ability of some inexperienced ewe lambs may be poor; however, ewes lambing at 1 yr of age tend to be better mothers throughout their lifetime than ewes lambing at older ages (Dýrmundsson, 1981). Breed selection may take advantage of breed differences for mothering ability (Snowder and Knight, 1995). Milk production of ewes lambing at 1 yr of age is generally lower than that of older ewes (Snowder and Glimp, 1991; Snowder et al., 2001a), but selection for milking score may improve first-lactation performance (Snowder et al., 2001b). Because ewe lambs are bred before they have reached mature size, pregnant ewe lambs require a higher nutrient intake to meet their growth and gestation requirements. The profitability of breeding ewe lambs

may be questionable for some production systems. The percentage of pregnant ewe lambs will depend on year, age, weight, and breed, as reported in the current study.

In summary, age and weight at breeding and total postweaning weight gain to breeding affected fertility and prolificacy in one or more of the four breeds. Fertility and prolificacy of the Polypay was not influenced by age and weight at breeding, which may be related to its inherent ability for high reproductive rates. In the Rambouillet, there was an advantage of breeding older and heavier ewe lambs to improve the probability of pregnancy. Increasing weight at breeding and the rate of postweaning gain in Targhee ewe lambs could increase the probability of pregnancy and of multiple births. Generally, increasing the value of any of the covariates increased fertility and prolificacy except for the Polypay, which was little affected by any of the covariates. In addition, there was variation between years of production, which is to be expected.

Implications

Reproductive performance of ewe lambs can be improved through breed selection and improved management. Fertility and prolificacy rates of Polypay ewe lambs are superior to those of Columbia, Rambouillet, and Targhee ewe lambs. Because Polypay ewe lambs are capable of achieving fertility rates of greater than 90%, commercial producers may find them to be the breed of choice when considering ewe lamb reproduc-

tive rates. This study also indicates that management practices can improve reproductive performance of ewe lambs. Increasing age and/or weight at breeding can increase the fertility of Targhee, Columbia, and Rambouillet ewe lambs. Some breeds may be more responsive to management changes. Response of fertility rate in Rambouillet ewe lambs to increasing age and weight at breeding will be greater than the expected response of Targhee and Columbia ewe lambs. The economic feasibility of applying these management practices will vary among production systems.

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